Regional Sediment Assessment

Project Report for Phase I, Module 4

September 2004

Regional Water Quality Control Board
Central Coast Region

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1 INTRODUCTION

This project report describes work done by Regional Board staff and contractors on the Regional Sediment Assessment during the 2003/2004 fiscal year. The Regional Sediment Assessment is a project to develop a programmatic approach to acquiring and putting to use knowledge of water quality affected by sediment in the Central Coast Region. This report specifically reviews work done on Phase I, Module 4 of the Assessment.

1.1 Project Purpose

The purpose of the Phase I, Module 4 project was to evaluate protocols that measure sediment conditions that support anadromous fish, and that can be used for assessing erosion and sedimentation during site investigations, inspections, and surveillance. The emphasis of this project was on refining and, if necessary, modifying a limited number of region-specific protocols. Additionally, we anticipated that the data generated would be of sufficient quality for use in future assessments and current TMDL monitoring.

1.1.1 Project Objectives

This project had the following objectives:

1) Determine effectiveness and feasibility of protocols and identify modifications as needed. Protocols were evaluated for:
   a) Level of effort required to implement
   b) Appropriateness for use in Region 3 at a reconnaissance level and for quantitative information gathering.
   c) Capacity to yield analytical evidence of sediment effects on salmonids. For example, do embeddedness data provide evidence of conditions supportive of steelhead?
2) Apply protocols to the range of conditions (e.g., disturbed/undisturbed, coastal/interior, east-side/west-side) currently or historically supporting salmonids in the Central Coast Region.
3) Develop a usable preliminary data set, including data on baseline conditions and possible reference conditions. Use data to support monitoring programs for adopted TMDLs in the Morro Bay and San Lorenzo River watersheds.
4) Refine Region 3's sediment data analysis and management tool.

In the project proposal (November, 20, 2003) these objectives were restated as hypotheses:

Hypothesis 1: The protocols for describing the active bed matrix of streams require a reasonable level of effort; are appropriate for quantitatively describing conditions in Region 3; can yield evidence of sediment effects on salmonids.

Hypothesis 2: The protocols for assessing sediment conditions for site investigations, inspections, and surveillance require a reasonable level of effort; are appropriate for qualitatively describing sediment conditions in Region 3.

1.2 Final Project Compared to Proposed Project

In the course of conducting this investigation staff made alterations to the scope of work as appropriate without altering the project objectives. These alterations included changes in the specific sampling locations and modifications in how samples were analyzed. Restricted access and substrate quality at the proposed Arroyo Seco River site resulted in that waterbody being dropped and the Upper Nacimiento River being added to represent interior valley waterbodies. Similar constraints associated with the Los Osos Creek site resulted in staff selecting in its place, Chorro Creek as an example of a coastal (south) waterbody. The Lompico Creek site was also dropped because of constraints on staff time and because the coastal (north) subregion is well represented by three other waterbodies in this study.

1.2.1 Untested Protocols

An important project objective was to test, and if necessary modify, protocols. Staff did in fact test and revise several protocols and these are discussed below. However, at the outset, staff recognized that the protocols at the center of hypothesis 2, above, would be difficult to "test" in any conventional sense of the word. The three protocols for site investigations, inspections, and surveillance included: 1) visual channel inspections to document sediment accumulation, 2) sediment transport corridors, and 3) photo monitoring. Both logistic and time constraints motivated staff to leave these protocols aside in this testing and refinement phase. The value and potential utility of the protocols was not in question, but the context in which they are likely to be used made it difficult for staff to construct an appropriate test. For example, photo monitoring requires an initial sequence of photographs capturing baseline conditions, and a later sequence documenting change from those conditions. Staff was presented with no "before and afer" opportunity to evaluate this protocol. The principal constraint on testing the protocol for sediment transport corridors was access. The protocol requires the freedom to follow a course of sediment to its source. Generally, this would require access to private land. Recognizing the obstacles inherent in this protocol, it is probably one that would be employed in somewhat rare circumstances, though Timber Harvest Plan post-harvest inspections are a likely candidate.

1.3 Background

A chief objective of the Regional Sediment Assessment program, of which this project is a part, is to provide tools to develop a clear definition of the sediment problems affecting water quality throughout the Region. Staff believes this will require assessment work at both a regional and site-specific scale, as well as support functions such as data management and training. The program is comprised of the following modules:

Module 1 — Program guide
Module 2 — Guide to accurate identification of sedimentation impacts in Region 3
Module 3 — Sediment problems in Region 3
Module 4 — Sediment assessment and monitoring protocols
Module 5 — Data store and information management
Module 6 — Staff training plan

A principal component of the program is a compendium of sediment assessment and monitoring protocols (Module 4). The full scope of this module is revealed in the Regional Sediment Assessment Program outline (Appendix A). The current project, Phase I, seeks to develop a portion of Module 4 by refining and field-testing protocols[1] for in-stream lotic systems and for site investigation, inspections and surveillance purposes. This project also further develops a data analysis and management tool envisioned as part of Module 5 of the Regional Sediment Assessment Program.

2 LOCATIONS

To develop the protocols, staff selected streams throughout the region based on the following criteria:
Essential Features:

- Accessibility
- Salmonid habitat: spawning gravels, pools, and flow

[1] Protocols (after the Greek *protókollon*, a first leaf glued to the front of a manuscript and containing notes as to its contents) here describe the procedures for obtaining samples and analyzing them, or making measurements *in situ*. Protocols may, but do not necessarily, include analytical methods. The terms "protocol" and "method" are not interchangeable.

- Available information on condition of fishery

Range of conditions affected by:

- Geology: poorly consolidated sedimentary deposits, consolidated sedimentary and metamorphic rock, granite.
- Watershed Disturbance: including open space, urban, rangeland, timberland, and agriculture.
- Hydrologic (flow) condition: regulated, unregulated, partly regulated, urban.

Table 2-1 presents the general characteristics of sites where protocols were tested. Staff made an effort to find steelhead trout-bearing streams covering the range of conditions occurring in the Central Coast Region.

Table 2-1 Characteristics of sites where protocols were tested

	DOMINANT CONDITION of WATERSHED CONTRIBUTING AREA		
	Geology	**Watershed Disturbance**	**Hydrologic Condition**
Coastal (North)			
Aptos Creek	Poorly consolidated sedimentary deposits	Open Space, Recreation	Unregulated
Valencia Creek	Poorly consolidated sedimentary deposits	Urban residential	Partly regulated
San Lorenzo River	Consolidated sedimentary and metamorphic	Urban residential, timberland, open space	Partly regulated
Coastal (South)			
Santa Rosa Creek	Consolidated sedimentary	Open Space, Rangeland	Unregulated
Chorro Creek	Consolidated sedimentary and volcanic	Open Space, Agriculture	Partly regulated/effluent dominated in dry season
Interior Valley			
Upper Nacimiento River	Granite and consolidated sed. and metamorphic	Open Space	Unregulated
Hilton Creek	Consolidated sedimentary and metamorphic	Open Space	Regulated

3 PROTOCOLS EVALUATED

Staff tested several protocols for this project including three that parameterize the active bed matrix of stream channels where anadromous fish are known, or suspected, to spawn (Table 3-1). Three others that have broad utility for site investigation, inspections, and surveillance purposes were not tested as planned. The protocols are described briefly here. Full versions are found in Appendix B, which includes descriptions of required procedures, equipment, quality assurance/quality control measures and field data forms.

Table 3-1 Protocols tested for this project, including number of samples collected or measured.

	Aptos Creek	Valencia Creek	San Lorenzo River	Santa Rosa Creek	Chorro Creek	U. Nacimiento River	Hilton Creek
	4/1/04	5/7/04	6/10/04	12/3/03	12/4/03	4/14/04	12/17/03
Measurements of Active Bed Matrix							
McNeil Bulk Sample	3	3	2	2	3	3	3
Pebble Count	3	3	2	2	3	3	3
Embeddedness	50	39	43	1	0	6	27
Site Investigation, Inspections, and Surveillance Protocols							
Visual Channel Inspections	0	0	0	0	0	0	0
Sediment Transport Corridors	0	0	0	0	0	0	0
Photo-monitoring	0	0	0	0	0	0	0

McNeil Bulk Sampling
The principal focus of Region 3's bulk sampling procedure is the geomorphic feature from which spawning gravels are derived—typically the riffle crest at the tail of pools. This protocol involves collecting sediment from the streambed, sieving it, and measuring the amounts of the different particle size fractions. The result is a particle size distribution representative of the area sampled. Staff developed this protocol from several that have been employed for similar purposes in other parts of the state.

Pebble Count
This protocol is also intended to provide information on the particle size distribution of the active bed matrix of the stream. Staff derived this protocol from one developed by the Sotoyome Resource Conservation District. Staff conducted pebble counts and collected McNeil samples in the same gravel feature in order to compare results, taking care to avoid disturbing the substrate and affecting the sample. The protocol also includes instructions for drawing a map of the stream channel where the sampled feature is located.

Embeddedness
Embeddedness quantitatively measures the extent to which larger particles are embedded or buried by fine sediment. The basic procedure is to remove a particle from the streambed and measure its total height and embedded height perpendicular to the streambed surface. Staff selected the procedure for measuring embeddedness from the Sotoyome Resource Conservation District field protocols.

Visual Channel Inspections to Document Sediment Accumulation
This inventory of sediment accumulation is intended for use during a stream reconnaissance that involves walking up a creek. The procedure is simply to note aspects of sediment accumulation, such as: recent sediment accumulation; gully, sheet, or rill erosion; channel instability or visible bank erosion, e.g., depositional features such as islands or bars, sediment plumes, or changes in bed level.

Sediment Transport Corridors
The protocol for mapping and describing Sediment Transport Corridors (STCs) is straightforward and has applicability in a variety of circumstances encountered by Region staff. Our intent was to field-test this protocol in several of the creeks where other protocols were evaluated. One anticipated difficulty with this

protocol was access to areas where the STC originates—the “source.” Another challenge is scheduling sufficient time in the field when the number of corridors and their lengths are not known ahead of time.

Photo Monitoring

Staff selected the State Water Resource Control Board’s Clean Water Team photo monitoring protocol to evaluate for its suitability in Region 3 sediment assessment and monitoring. Again, our intent was to test out this protocol on several of the creeks. Staff was to determine the level of effort required to establish photo points and manage field data for this protocol.

4 RESULTS

4.1 Protocols

4.1.1 Field Methods Critique

Staff collected 57 bulk sediment samples to determine particle size distribution of spawning gravels in seven streams in the Central Coast Region. Where possible, staff relied on fisheries biologists to recommend stream reaches where spawning is known or suspected to occur. Prior to entering the field, we combined their suggestions with other information concerning stream gradient, site access, and expected flow conditions to select reaches for reconnaissance and subsequent sampling. Upon arrival in the field, staff qualitatively assessed habitat conditions, including grain size, flow, and water depth. For example, the Arroyo Seco River reach, and the backup reach on Willow Creek, were rejected upon arriving in the field to discover a landslide restricting access to one reach and grain sizes far too large to support spawning by steelhead in the other.

Identifying a Sampling Population

The greatest challenge in sampling potential spawning gravels for particle size analysis is identifying the appropriate feature to sample. Existing protocols do not adequately address this, since they are written for use in a variety of substrate conditions. Our intended use is specific to potential spawning gravels, so clear and accurate identification of such features is an essential first step in collecting a representative sample.

Once we determined the potential for spawning and the feasibility of sampling, staff identified the specific feature to sample (Figure 4-1). Typically this was a riffle crest feature at the downstream tail of a pool, but accumulations of gravels and appropriate flow condition also were observed in runs and in transitional areas between runs and riffles. We then drew a map of the feature in the context of the stream channel, indicating habitat conditions and structural features potentially affecting those conditions, e.g., location of nearest upstream and downstream habitat feature, flow direction, infrastructure, width of channel, etc. Without a fisheries biologist present to confirm that a feature was in fact spawnable, staff lacked confidence is some of the features selected. Hilton Creek was an exception, since fisheries biologist Scott Engblom of the Cachuma Operations and Management District accompanied staff into the field and located features that were used by spawning steelhead in previous seasons. We also found it difficult to visually define the dimensions of a feature (where it begins and ends). A map of the feature and its context was prepared for each sampling location.

Figure 4-1 Staff lays out measuring tapes over the gravel feature center point to guide sampling.

Bulk Sampling

The McNeil bulk sampler used by staff has a 15cm sampling tube diameter and is an exact replica of a sampler used by California Department of Fish and Game in the Central Coast region. The diameter is roughly twice that of the expected median particle size (D50 = 69mm) of salmonid spawning gravels. The 15-cm diameter constrains the size of sampled gravel and results in an unknown degree of truncation. Staff extracting cores frequently encountered difficulty inserting the lower coring tube into the gravels to the full depth of 14cm when a portion of the tube's leading edge was blocked by a large particle. This necessitated relocating the sampler and attempting to penetrate the substrate in a new location within the potential spawning gravel population. At times the only way to collect a complete sample was to excavate by hand the substrate below the lowest elevation of the sampler Figure 4-2. This is not generally an acceptable approach to sampling with the McNeil sampler as it introduces bias toward particles large enough to grab hold of.

This and other problems in sampling populations containing larger particles could potentially affect site selection decisions and ultimately skew the data toward smaller particle size distributions that are more easily sampled. Staff is aware of this potential source of error and has considered alternatives to the corer, such as shoveling a sample directly from the substrate. However, we are not convinced of the accuracy of a shovel method over that of the McNeil method. We believe awareness of the problem combined with consistency in site selection and use of a single coring device throughout the region are the most appropriate measures to insure data quality.

Figure 4-2 McNeil sampling on the Upper Nacimiento River

Field Sieving
Staff conducted sampling and wet-sieving, according to the initial protocol, at the first sampling location, Reach 1 on Santa Rosa Creek. We immediately recognized that the time required to conduct volumetric analysis in the field with moist samples was beyond that available to Regional Board field staff. Therefore, staff decided to voucher remaining samples in sealable bags for transport to a laboratory where dry sieving could be conducted. Staff modified the procedure and developed a new field sheet to track sample extraction, vouchering, and the Imhoff cone fine-fraction settling procedure (Appendix B).

Pebble Count
Staff conducted pebble counts according to the procedure without difficulties (Figure 4-3). We improved the instructions for measuring particles, revised field sheets to improve the recording of measurements, and created a template for drawing a map of the stream channel where sampling is conducted (Appendix B).

Figure 4-3 Pebble counting on Aptos Creek

4.1.2 Embeddedness

Staff endeavored to determine whether cobble embeddedness is a parameter that can be obtained with reasonable effort and used with confidence. Our conclusion is that, while relatively straightforward in concept, execution of the protocol and the results obtained from it are rife with shortcomings. Our experience correlates well with a broader critique of the method conducted by U.S. Forest Service fisheries biologists and hydrologists in 1988. These scientists reviewed literature and shared experiences to try and develop a standard approach or method for embeddedness. They identified several limitations:

- Cobble embeddedness exhibits high spatial and temporal variability in both natural and disturbed streams. Sampling must be intensive to detect changes.
- Cobble embeddedness should be a measured parameter. However, visual assessments may provide information adequate for characterization purposes.
- Embeddedness measurements are most applicable in granitic watersheds or other geologies where sand is an important component of the annual sediment load and substrate.
- Cobble embeddedness is best applied to streams where embeddedness is suspected or known to limit salmonid rearing.
- Repeat monitoring must be conducted at the same site because of high instream variability.
- Application of the method in streams less than 20 feet wide may destroy sites for future monitoring.
- Cobble embeddedness is most appropriate for stream-to-stream comparisons of similar reaches or for measuring temporal changes in the same reach (Sylte and Fischenich, 2003, pp. 2, 3).

They arrived at the following conclusions:

1. The ability of embeddedness to detect changes due to land management activities is unclear and results have rarely been published in peer-reviewed literature.
2. Without additional research addressing the reliability of embeddedness outputs from the various methods, use of embeddedness as standards and guidelines or to link embeddedness to biological criteria currently appears highly questionable." (Ibid., p.4).

While our approach inherently resolved some of the limitations identified by these scientists (e.g., we applied it in streams where embeddedness is suspected or known to limit salmonid rearing), we feel it is highly susceptible to many of the others. Additionally, we would argue that taken alone, it is an inadequate characterization of substrate conditions, and combined with particle size distribution data obtained through bulk sampling or pebble counts, it adds little value.

Used as a relative gage of conditions within a reach or a watershed, the method is potentially useful. For example, the Aptos Creek Watershed Assessment and Enhancement Plan fisheries study (Hagar, 2003) reported embeddedness data for the mainstem and tributaries of Aptos Creek. All data were collected in potential spawning gravels, during one season, by one crew, and interpreted by an experienced fish biologist. That constrained approach would appear to optimize the value of embeddedness data.

4.1.3 New Lab Procedure

Staff did not anticipate the need to develop new lab procedures as part of this project. However, upon discovering that wet-sieving of gravel samples in the field required more time than available to staff for this project, staff made arrangements for samples to be dry sieved in a laboratory. Staff converted a portion of an existing contract with California State University, Monterey Bay (CSUMB) to fund processing and analysis of samples at their laboratory and to procure equipment so that Regional Board staff could conduct this work in the future. CSUMB analyzed the samples according to specifications provided by staff. Dry sieving is far more accurate and can be conducted in a controlled environment using automated equipment to reduce staff time.

CSUMB modified a procedure included in their Protocols for Water Quality and Stream Ecology Research (Watson, et al., 2003) for sieving the bulk sample into fractions smaller than 37.5, 31.5, 16, 8, 6.3, 4, 2, and 0.85 mm. A full write-up of CSUMB's analytical procedure is forthcoming.

4.2 Data Analysis

4.2.1 Analysis of Bulk Samples

Primary measures applied to the size distributions determined through sieving correspond to numeric targets for sediment TMDLs throughout the State. These include: dry-weight percent finer than 0.85mm, dry-weight percent finer than 6.3mm, and median particle size diameter (D50). Percentiles of 16 and 84 (one standard deviation) and 5 and 95 (two standard deviations), were also calculated, as were measures of geometric sorting, geometric mean, and skewness:

- Geometric sorting index (sg = (D84/D16)E0.5) for a perfectly sorted sample has a value of 1. An sg of less than 2.5 indicates a well-sorted sediment, about 3 is considered normal, and above 4.5 is poorly sorted.
- Geometric mean particle size (dg = (D84*D16)E0.5), like the median, is a measure of central tendency, but one more influenced by extremes of the distribution than the median. It is commonly used as an indicator of streambed material permeability. Permeability generally increases with an increase in dg, though sorting can affect it.

- Skewness (sk = log (dg/D50)/log(sg)) measures the asymmetry of the particle size distribution. Redd (salmon nest) gravels are usually negatively skewed; their size distributions are not perfectly log normal but are negatively skewed with tails extending into the fine sediment sizes. This is also reflected in the tendency for D50 to exceed dg. (See Bunte and Abt, 2001 for a complete discussion of measures of particle size distribution and statistical evaluations of those measures.)

Regional Variability

The overall particle size distributions for potential spawning gravels range broadly among the streams sampled (Figure 4-4). Box and whisker plots reveal bulk sample gravel distributions that are confined to smaller particles for some streams (Chorro Creek) and span larger sizes in others (Aptos Creek). The plot for Valencia Creek's gravel distribution shows the smallest D16, indicating that the overall distribution is skewed toward finer particles there. Chorro Creek had the smallest overall range of particle sizes.

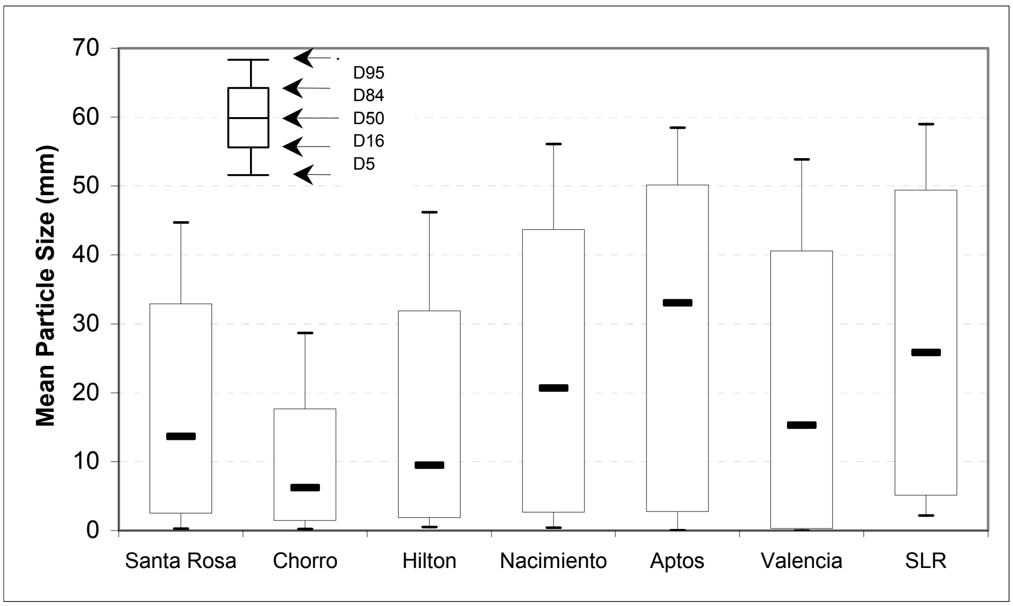


Figure 4-4 Streambed particle size percentiles for all sites, all features.

The median particle diameters for streams sampled range from 6.25mm to 33mm, and are substantially smaller than diameters generally considered ideal for spawning (Figure 4-5). Santa Rosa Creek, Chorro Creek, Hilton Creek and Valencia Creek all have D50s averaging less than 20mm in diameter—less than one third the diameter optimal for steelhead (69mm), according to literature derived principally from salmon-bearing streams of the Pacific Northwest, which suggest that fish can move gravels with a median diameter up to about ten percent of their body length. Minimum D50 values are also similarly depressed relative to the target of 37mm, with no stream's minimum D50 greater than 11mm.

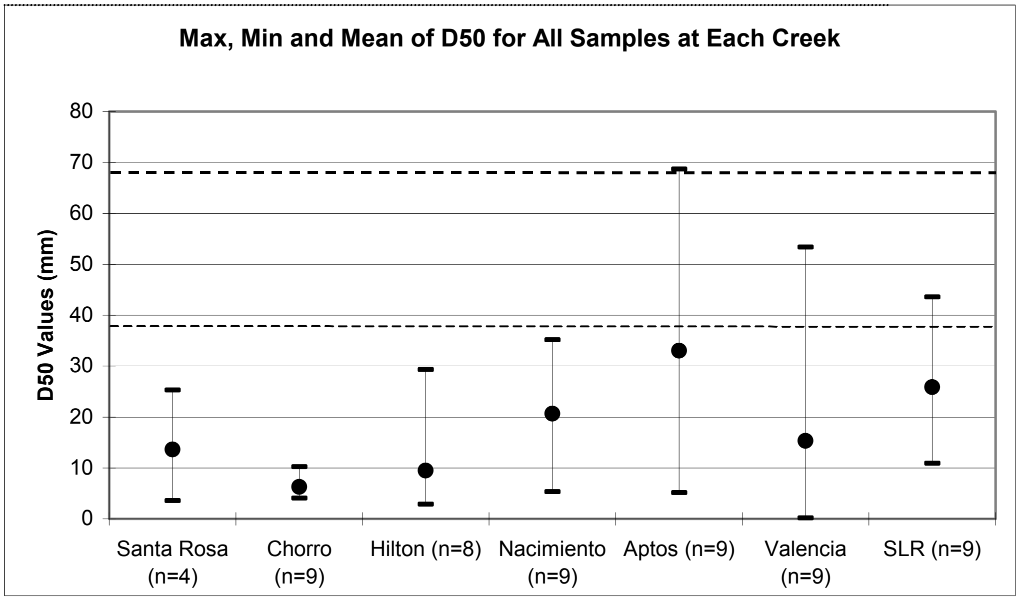


Figure 4-5 Median particle diameters compared to numeric target values of 37mm minimum, and 69mm mean.

Variability Between Features in a Single Reach

Cumulative Frequency Curves

The range of sizes present in natural gravels is typically presented in cumulative size distribution curves (Kondolf, 2000, p. 263). The cumulative frequency curves are useful for comparing particle size distributions for bulk samples from several features in a single reach. Each feature's cumulative frequency curve is derived from the average of multiple samples, usually three, that were sieved separately to calculate cumulative percentages for each size class. Features (sites) within a single reach generally displayed similar patterns in their cumulative frequency curves (Appendix C). Exceptions included Santa Rosa Creek and Hilton Creek, which both had wide separation between curves representing features in the reach. The curves show calculated (interpolated) percentiles of 16, 50, and 84 superimposed for comparison with the curves. The curves are based on the actual cumulative percentages and in some cases diverge from interpolated percentiles (e.g., Valencia Creek).

Histograms of Cumulative Percent

Figure 4-6 and Figure 4-7 display histograms of cumulative percentages for two key size classes of gravel—0.85mm and 6.3mm. These two classes are important for steelhead incubation in, and emergence from, the redd. Most potential redds that we sampled had cumulative percentages of the finer fraction that are below a key numeric target used for sediment TMDLs in the California (Figure 4-6). Only Valencia Creek appears to exceed this level. However, most features had higher cumulative percentages of the 6mm size class—an indication that fry emergence from the redd may be negatively affected (Figure 4-7).

The histograms also reveal that features within each reach range considerably for each of the two size classes considered. However, differences between reaches are evident as well. Valencia Creek, for example is distinct from Upper Nacimiento River.

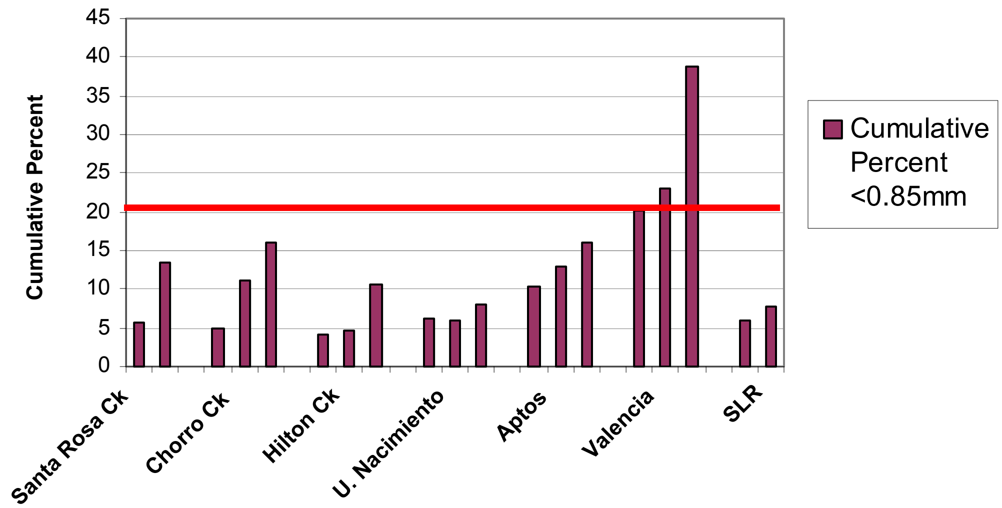


Figure 4-6 Variability in cumulative percent <0.85mm. This size class is most relevant to incubating salmonids, which require permeable gravels. The bar represents a maximum used as a numeric target in sediment Total Maximum Daily Loads.

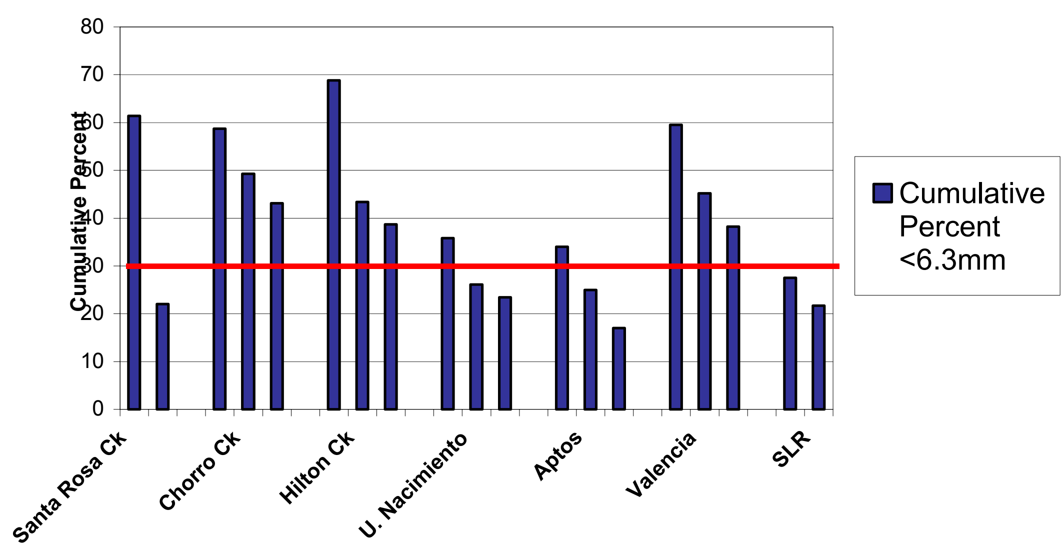


Figure 4-7 Variability in cumulative percent <6.3mm. This size class is most relevant to emergence of salmonid fry through the redd gravels. The bar represents a maximum used as a numeric target in sediment Total Maximum Daily Loads.

Skewness and Sorting
Bulk samples from Hilton Creek (two samples) and Valencia Creek (one sample) were the only ones to display positive skewness. All other samples were negatively skewed as is typical of spawning gravels. Sorting of gravels in the features sampled is generally poor with values greater than 4.5 being common. Valencia Creek had the highest sorting indices (poorly sorted) with average values of approximately 25, 14, and 18 for the three features sampled. These high values result from very high cumulative percentages of fine particles.

Variability Between Samples within a Single Feature

Staff evaluated summary measures of gravel size using averages for each feature—in effect presenting a data composite of the two to five samples collected at a feature. However, these averages tend to conceal variability within a single feature. An examination of intra-feature variability is useful in determining the representativeness of a sample, and should be included in a more complete quality assurance protocol that includes data acceptability criteria. A cursory look at variability in the median and geometric mean particle size of individual sample populations reveals both good and poor correlation (Table 4-1). For example Chorro Creek samples tended to be similar to one another, while Valencia Creek ranged widely (see feature 3). Geometric means, which reflect the extremes of the particle size distribution, tend to be less than the medians because the samples are negatively skewed with tails extending into the fine sediment sizes.

Table 4-1 Comparison of individual bulk samples: median and geometric mean particle size of population

	Santa Rosa		Chorro		Hilton		Upper Nacimiento		Aptos		Valencia		San Lorenzo	
Sample & Feature #	Median	*Geo. Mean*	Median	*Geo. Mean*	Median	*Geo. Mean*	Median	*Geo. Mean*	Median	*Geo. Mean*	Median	*Geo. Mean*	Median	*Geo. Mean*
	Millimeters													
1	3.6	*3.4*	4.1	*4.0*	11.1	*8.6*	27.9	*10.8*	40.5	*22.7*	0.2	*0.3*	36.8	*18.1*
2	4.2	*4.2*	4.7	*3.3*	8.2	*7.3*	5.4	*5.0*	34.9	*13.8*	8.1	*2.6*	39.8	*32.2*
3			4.3	*2.1*	13.0	*11.0*	16.4	*10.2*	34.7	*12.7*	5.0	*1.7*	13.3	*7.8*
4													43.6	*21.7*
5													24.3	*10.0*
Feature 1 Avg.	**3.9**	***3.8***	**4.3**	***3.2***	**10.7**	***9.0***	**16.6**	***8.7***	**36.7**	***16.4***	**4.4**	***1.5***	**31.5**	***20.1***
1	21.5	*10.9*	7.5	*5.4*	29.3	*12.7*	35.2	*13.5*	16.3	*5.8*	6.3	*2.7*	17.2	*6.4*
2	25.3	*17.0*	6.1	*4.6*	8.4	*7.6*	29.9	*14.3*	68.7	*8.7*	19.2	*3.5*	10.9	*6.7*
3			5.5	*4.5*	4.7	*6.6*	11.6	*6.6*	41.1	*12.7*	11.1	*4.2*	39.7	*14.0*
4													32.3	*18.8*
Feature 2 Avg.	**23.4**	***14.3***	**6.3**	***4.9***	**14.2**	***8.8***	**25.6**	***11.5***	**42.0**	***9.0***	**12.2**	***3.5***	**20.2**	***10.6***
1			10.2	*8.7*	4.2	*7.2*	23.6	*15.18*	39.5	*10.6*	5.7	*1.1*		
2			4.5	*4.2*	2.9	*2.9*	16.8	*9.9*	5.2	*2.5*	53.4	*3.3*		
3			9.5	*7.0*			19.1	*10.5*	16.6	*7.5*	28.8	*7.3*		
Feature 3 Avg.			**8.1**	***6.7***	**3.6**	***5.2***	**19.8**	***11.9***	**20.4**	***6.9***	**29.3**	*3.9*		

Imhoff Analysis of Fine-Fine Fraction

Quantifying the proportion of potential spawning gravels comprised of fine sediment is of principal importance to this project and a key objective of the McNeil protocol. The wet sieve field method that staff initially followed includes an Imhoff cone method for quantifying the finer fractions in the sample wash that pass through a 0.85mm sieve. Once staff abandoned wet sieving in the field in lieu of vouchering samples for subsequent dry sieving in the lab, we continued to measure the volume of settled fines in the Imhoff cones because there is no other practical means by which to quantify this portion of the sample. We did this by draining the bulk sample from a bucket into the Imhoff cones through a 0.85mm sieve and waiting exactly ten minutes to record the volume of settled material (Figure 4-8). We also collected two samples of the settled material for determination of density (dry mass/wet volume) in the lab.

Staff then conducted an analysis of these Imhoff volume and density data to determine whether this fraction of sediment was a significant component of the total sample weight, or small enough to disregard. The Imhoff method requires a considerable investment of field time, so the implications of continuing to employ the method are obvious.

Total bulk sample weights ranged from 1,700g to 4,490g. Based on an average density of 216mg/mL (n=2) for the fines settled in Imhoff cones, the fine-fine fraction (<0.85mm) mass ranged from 0.756g to 154.4g. This represents from 0.02 percent to 4.43 percent of total sample weight. The median percent of total sample weight was less than 0.5. Thirteen of 57 samples had percentages over one percent. All samples with greater than one percent of total weight in this fraction had Imhoff sediment volumes greater than two liters. Staff did not include this weight in the calculation of cumulative percentages from the sieve analysis.

Figure 4-8 Imhoff cones are filled with water from McNeil sampler (transferred to bucket earlier).

4.2.2 Analysis of Surface Particle Counts

The pebble count protocol yields a size distribution for surface particles. While pebble counts and bulk samples measure different gravel populations, understanding how they relate may lead to more informed choices about where one protocol might be used over the other. Additionally, the surface:subsurface grain size ratio can be used as an indicator of sediment supply (Dietrich et al., 1989)—a purpose for which can be envisioned in the continued development of the Regional Sediment Assessment.

A comparison of median particle diameters in Central Coast potential spawning gravels, as measured in surface (pebble count) and bulk samples (McNeil core), is presented in (Table 4-2). This comparison indicates the expected trend of coarser surface populations, with two exceptions, Aptos Creek and Upper Nacimiento River, which had larger median diameters in the bulk sample than in the surface sample.

Table 4-2 Comparison of median particle diameter as measured from surface particles and bulk samples

Waterbody	Average D50 (mm)		Difference
	Pebble Count Surface	McNeil Core Bulk	
Coastal (North)			
San Lorenzo River	34.9	25.85	9.0
Aptos Creek	26.6	33.06	-6.4
Valencia	24.1	15.31	8.8
Coastal (South)			
Santa Rosa Creek	16.7	13.69	3.0
Chorro Creek	10.0	6.25	3.7
Interior Valley			
Hilton Creek	15.2	10.26	4.9
Upper Nacimiento	11.6	20.74	-9.1

4.2.3 Summary of Analytical Results

Results of this initial analysis of uncensored data indicate that gravels in the north are coarser than those from the southern coastal and interior valley streams. This is evident in the higher median diameters from both surface and bulk samples, and the lower percentages of particles less than 6.5mm (Table 4-3). At the same time, a known problem of excessive fine sediment in the northern streams is supported by these data. Northern coastal streams of the Central Coast Region have well documented high quality steelhead habitat and abundance and are more similar to salmonid habitats farther north, than to those of the southern steelhead, (south of Aptos Creek).

Table 4-3 Summary of measures of potential spawning gravels in Central Coast Region streams (uncensored data)

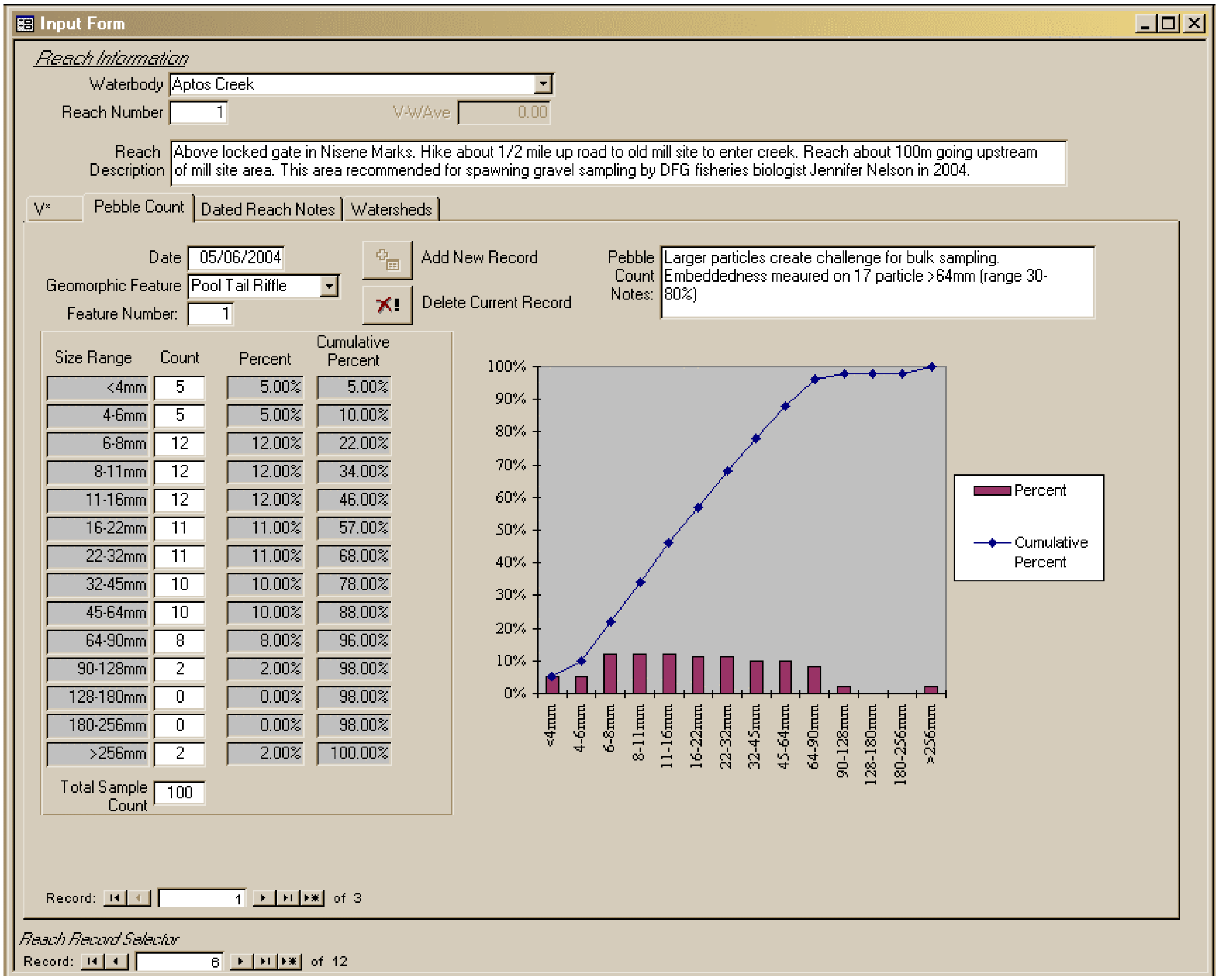
Waterbody	Date	Particle Size (mm)					Percent Finer	
		Surface	Bulk				than 0.85mm (Compare to 21%)	than 6.5mm (Compare to 30%)
		D50	N	D50		Geo. Mean		
		Mean		Mean	Min			
Coastal (North)								
San Lorenzo River	6/10/04	34.9	9	25.85	10.95	15.1	6.5%	23.3%
Aptos	5/6/04	26.6	9	33.06	5.17	10.8	13.2%	25.3%
Valencia	5/7/04	24.1	9	15.31	0.18	3.0	27.3%	47.7%
Coastal (South)								
Santa Rosa Creek	12/3/03	16.6	4	13.69	3.57	8.9	9.5%	41.7%
Chorro Creek	12/4/03	10.0	9	6.25	4.05	4.9	10.7%	50.4%
Interior Valley								
Hilton Creek	12/17/03	15.2	8	10.26	2.91	7.9	6%	48.0%
U. Nacimiento River	4/15/04	11.6	9	20.74	5.34	10.7	6.7%	28.3%

4.3 Data Management Tools

Data management tasks completed for this project included construction of data analysis and storage systems for pebble count data, McNeil bulk samples, and photo monitoring and field notes.

4.3.1 Pebble Count Data Management Tool

Staff developed an MS Access database exclusively for managing information from the Regional Sediment Assessment. Staff made the pebble count entry form closely match the field sheet format. A "notes" field was also added so that field notes could be entered (Figure 4-9).


Input Form

Reach Information

Waterbody: Aptos Creek

Reach Number: 1 V-WAve 0.00

Reach Description: Above locked gate in Nisene Marks. Hike about 1/2 mile up road to old mill site to enter creek. Reach about 100m going upstream of mill site area. This area recommended for spawning gravel sampling by DFG fisheries biologist Jennifer Nelson in 2004.

V* | Pebble Count | Dated Reach Notes | Watersheds

Date: 05/06/2004

Geomorphic Feature: Pool Tail Riffle

Feature Number: 1

Add New Record

Delete Current Record

Pebble Count Notes: Larger particles create challenge for bulk sampling. Embeddedness meaured on 17 particle >64mm (range 30-80%)

Size Range	Count	Percent	Cumulative Percent
<4mm	5	5.00%	5.00%
4-6mm	5	5.00%	10.00%
6-8mm	12	12.00%	22.00%
8-11mm	12	12.00%	34.00%
11-16mm	12	12.00%	46.00%
16-22mm	11	11.00%	57.00%
22-32mm	11	11.00%	68.00%
32-45mm	10	10.00%	78.00%
45-64mm	10	10.00%	88.00%
64-90mm	8	8.00%	96.00%
90-128mm	2	2.00%	98.00%
128-180mm	0	0.00%	98.00%
180-256mm	0	0.00%	98.00%
>256mm	2	2.00%	100.00%

Total Sample Count: 100

Record: 1 of 3

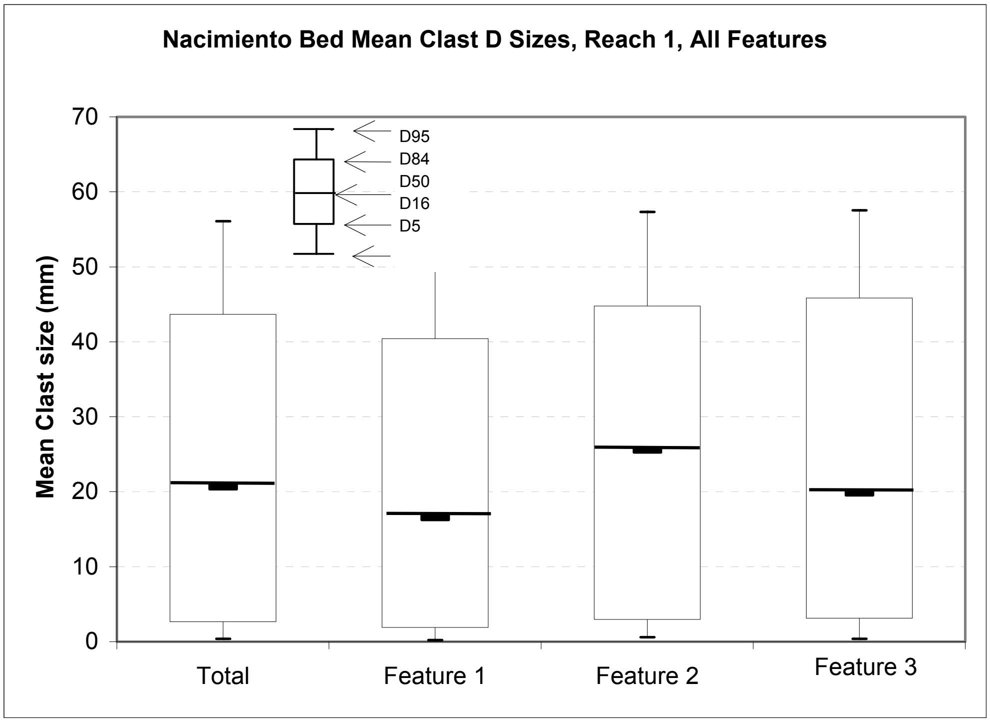
Reach Record Selector

Record: 6 of 12

Figure 4-9 Pebble count data entry sheet

4.3.2 Bulk Sample Data Management Tool

The Central Coast Watershed Studies team at California State University, Monterey Bay (CSUMB) processed bulk samples collected by Regional Board staff. CSUMB developed a MS Excel tool for entering data and calculating sample statistics, based on specifications provided by Regional Board staff. The spreadsheet tool allows the user to display summary statistics such as: tables, cumulative percentile curves, histograms, and box-and-whisker plots (Figure 4-10).



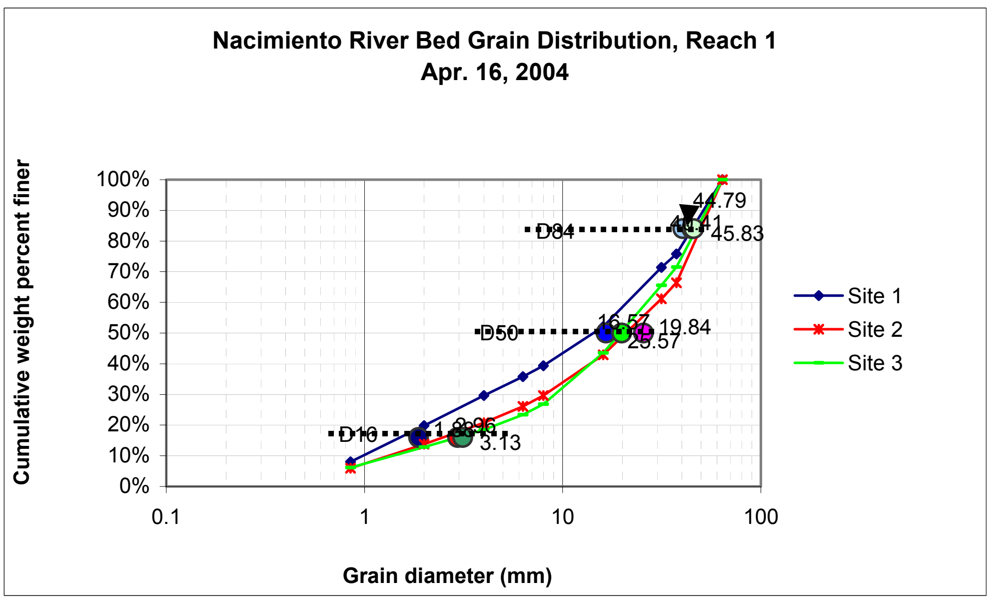


Figure 4-10 Example box-and-whisker plots, and cumulative frequency curves generated by the bulk sample data analysis and management tool.

4.3.3 Photo Monitoring Information Management

Staff developed forms in the MS Access database that allow the user to import photos (actually links to the photo file), and add metadata about the photos that can be searched. Data include waterbody, watershed, date photo was taken, photo caption (Figure 4-11). The photos can then be retrieved based on these attributes.

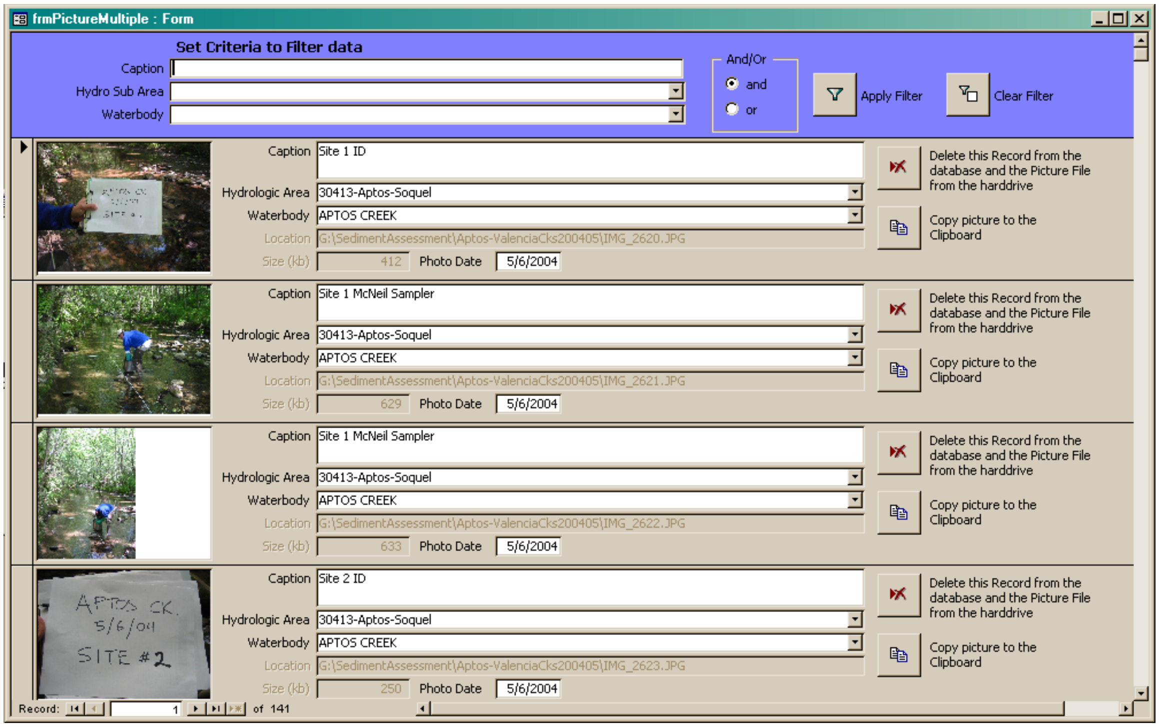


Figure 4-11 Photo monitoring data input form.

4.3.4 Field Notes Information Management

Field Notes can be entered at two different levels when working with the MS Access database tool: individual sample notes can be added on the corresponding sample tab (e.g. V* or Pebble Count), or, dated reach notes can be added on the Dated Reach Notes tab. Dated Reach Notes can be used to describe general conditions of the area, any antecedent conditions/events and any other data that is related to a particular field visit. Reach notes can be added at the reach level under reach description. These notes should describe the reach location and any other pertinent data that does not change over time.

5 DISCUSSION

5.1 Conclusions about Protocols

The chief finding from this project is that, with appropriate modifications, these protocols for describing the active bed matrix of streams require a reasonable level of effort, are appropriate for quantitatively describing conditions in the Central Coast Region, and can yield evidence of sediment effects on salmonids. Thus, staff is confident that hypothesis one is correct. We also observed patterns of variability in the data that were generally consistent with our initial expectations, offering another line of evidence that the protocols are appropriate for the uses to which we put them.

Several challenges persist relative to effective use of the protocols. First, site selection is an essential first step that will continue to be difficult without the expertise of fisheries biologists. Additionally, the 15-cm diameter coring tube constrains the size of sampled gravel and results in an unknown degree of truncation. However, we believe that awareness of the problem combined with consistency in site selection and use of a single coring device throughout the region are the most appropriate measures to insure data quality.

Staff is also convinced that a frequency or abundance term should be developed to give context to particle size measures. In this project we sampled two or three of the most distinct easily identifiable spawning features encountered in a reach, and recorded no information on overall frequency or abundance of features. A more complete assessment of sediment effects on spawning habitat would include some description of the availability of spawning gravels.

And finally, staff made adjustments and modifications to the protocols to ensure their utility. These changes included:

- Modifying the bulk sampling protocol to discontinue wet sieving in the field and instead collecting samples for subsequent dry sieving in the lab.
- Discontinuing Imhoff fine-fraction analysis when total sediment volume accumulated in the Imhoff cone is below a threshold value. Staff modified the protocol accordingly.
- Eliminating embeddedness from the protocols to be used in assessing regional sediment conditions.
- Creating a new procedure and procuring equipment for dry sieving, thus expanding Regional Board staff's capacity to conduct analysis of regional sediment conditions.

5.2 Analytical Results

While the principal objectives of this project were to determine effectiveness and feasibility of protocols, staff also intended to develop a usable preliminary data set, including data on baseline conditions and possible reference conditions in streams throughout the region. Staff anticipated that if the data were of sufficient quality, one possible use for them would be future assessments and current TMDL monitoring. Since we have not developed acceptability criteria for the data generated by this project, all data were considered, including those that may be outliers or disqualified according to criteria developed in the future. The following results are then based on what is currently a preliminary data set.

As expected, there is a range of conditions among potential spawning gravels in the streams of the Central Coast Region. Variability at regional, reach, and feature level were evident in the data. Within the region, particle size distributions represent finer classes than are optimal for spawning steelhead, based on published literature values. The degree to which this finding is an artifact of the sampling procedure, which may not capture enough large particles, is unknown and should be characterized in future work.

The findings are also generally consistent with staff's expectations and current knowledge of relative habitat quality in Central Coast streams. For example, the data indicate that gravels in the north tend to be coarser than those in the southern coastal and interior valley streams. At the same time, the well-documented problem of excessive fine sediment in some northern streams is supported by these data.

At the reach level, features (sites) within a single reach generally displayed similar patterns in their particle size distributions. Most potential redd gravel that we sampled had cumulative percentages of the finer fraction that are below a key numeric target used for sediment TMDLs in the California. However, most features had higher cumulative percentages of the coarse-fine (6mm) size class—an indication that fry emergence from the redd may be negatively affected.

Variability in results at the feature level points to the challenges inherent in collecting representative samples from potential spawning gravels. Nevertheless, the comparison of surface and bulk samples from a single feature indicates the expected trend of coarser surface populations.

Percentages of fine-fine fraction sediments estimated through the Imhoff method indicate this fraction is typically less than 0.5 percent, but may be up to approximately 4.5 percent.

5.3 Peer Review

Staff submitted the proposed workplan for this project to all Region 3 technical staff, as well as our staff counterparts in Regions 1 and 2 for their review and comment. Additional and more detailed review was also performed in a half-day workshop on February 27, 2004 with participation of Region 2 staff. These reviews resulted in only minor changes to the project.

Region 3 staff also requested from Tetra Tech, Inc. a review of the Module 4, Phase I project and of the general scope of the Regional Sediment Assessment. We sought advice and comments specifically relating to:

1) Clarifying the intent of the program,
2) Determining whether the strategy for developing the program is appropriately scaled to the problems of sedimentation in the region,
3) Identifying and clearly defining specific products of the program,
4) Establishing the utility of the program for developing 305(b) assessments, 303(d) listings, TMDL development, and for conducting surveillance and investigations pursuant to regulatory programs, and
5) Phasing of the work.

Tetra-Tech's review provided a useful third-party perspective on the specific project at hand, as well as the overall approach to assessment of sediment conditions throughout the Central Coast Region. Below is a summary of the salient issues that Tetra Tech identified in their review, along with staff's response. The entire text of Tetra Tech's review is included in (Appendix D).

Clarifying intent of program.

<u>TT Comment</u>: It may be premature to test specific protocols before completing the bigger picture analysis of why specific protocols are needed. Specifically, it would be useful to frame the Regional Sediment Assessment and clarify its intent using the Problem Formulation elements (conceptual model, risk hypotheses, assessment endpoints, and measures of effect) of Ecological Risk Assessment. A key component of Ecological Risk Assessment is the development of a conceptual model and associated risk hypotheses. The conceptual model consolidates available information on ecological resources, stressors, and effects and describes, in narrative and graphical form, relationships among human activities, stressors, and the effects on valued ecological resources. Developing the conceptual model provides a forum for discussion, a framework for understanding and explaining the hypothetical relationships and the scope of assessments, and a structure for the forthcoming analyses. The conceptual model can also serve as a valuable integrating summary of existing conditions, existing and potential future threats, and management opportunities.

<u>*Staff Response*</u>*:* Staff recognizes the value of a conceptual model and anticipates that at a minimum, a selection of conceptual exercises will be employed at specific junctures in program development. However, we do not believe that an all-encompassing risk assessment process should be followed at the expense of time and resources that could be directed toward development of more immediately practical tools. Staff continues to discuss the issue of adequately "framing" the approach to sediment assessment and expects to document that approach in a forthcoming staff report (December 2004).

Is the program appropriately scaled to the problems of sedimentation in the region?

<u>TT Comment</u>: The only suggestion we have is to proceed as soon as possible with further development of Module 2 (Guide to Accurate Identification of Sedimentation Impacts in Region) and Module 3

(Sediment Problems in Region 3) with an eye to determining proper scales of evaluation associated with different types of sediment problems in the region.
Staff Response: Staff will pursue these modules as time and resources permit. Module 3 is the subject of work proposed in the current fiscal year.

Identifying and defining specific products of the program.
TT Comment: The specific products of the program are clearly defined in the overall outline (Appendix A). What is less clearly defined at this point is how the specific products fit into various regulatory commitments of the Regional Board.
Staff Response: Staff agrees.

Utility of the program for developing 305(b) assessments, 303(d) listings, TMDL development, and for conducting surveillance and investigations pursuant to regulatory programs.
TT Comment: The proposed work will clearly support the whole range of regulatory programs associated with evaluating and maintaining aquatic life support. However, the outline provided contains only brief placeholders on this topic, and it may be advisable to add a Module 7 that would explicitly address use of the assessment products in specific regulatory contexts, as well as referring to appropriate complementary guidance (such as the *Protocol for Developing Sediment TMDLs*).
Staff Response: Staff agrees with the need to explicitly identify how assessment products would be used in specific regulatory contexts.

Phasing of the work.
TT Comment: As noted above, the protocols being tested in Phase I of Module 4 are appropriate. However, it would seem advisable to pursue at least initial development of Module 2 – which provides the justification of these efforts – as soon as is possible.
Staff Response: Staff agrees that completion of Module 2 would support continued development of the Regional Sediment Assessment Program.

Notes on Phase I Protocols.
TT Comments:

- Embeddedness has a somewhat mixed history of success. In general, embeddedness has been thought to be appropriate to gravel bed streams, but of less value in determining habitat quality in sandy streams and low-gradient warm-water fishery streams. Replicability of embeddedness measures obtained at a single site has also been a problem.
- For all three active bed matrix measures, it would be desirable to do some further work on precision and replicability in Central Coast Region streams.
- The McNeill and Pebble Count procedures do contain a discussion of replicability and bias, with QA/QC recommendations. This component is important and should be pursued.
- In lieu of the proposed protocol for visual assessment, staff should probably start from the basis of a tested and clearly defined visual inspection method (for example, one such as the NRCS [1999] *Stream Visual Assessment Protocol*) that provides explicit instructions and standardized recording forms and scoring criteria.

Staff Response: Because staff shares the concerns about embeddedness, the protocol has been retained only as an optional procedure for descriptive purposes. Staff agrees that more work is needed on precision and reproducibility of the protocols. Staff did not test the visual assessment protocol initially proposed. However, we are interested in a very simple and rapid approach. The NRCS protocol is more comprehensive in nature, but may provide a good basis for deriving an approach that meets our objectives.

6 RECOMMENDATIONS

6.1 Protocols

Staff recommends several actions relative to improving the protocols. These include,

- Refine the channel and reach selection criteria and guidance developed previously (Appendix E). Consult other approaches such as that developed for Simpson Timber Company (House, 1999).
- Solicit appropriate fisheries expertise in selecting features and determining when to sample.
- Develop and implement an assessment of overall abundance of spawning features to correlate with findings from analysis of particle size distributions of such features.

6.2 Sample Collection and Analysis

Staff has not developed data acceptability criteria for the data generated by this project. Our most significant recommendation is that such criteria be developed prior to any future sample collection and analysis. These criteria could be incorporated into a comprehensive quality assurance project plan for the Regional Sediment Assessment Program that would include data quality objectives.

6.3 Data and Information Management Tools

Staff and contractors developed two very useful, but discrete software tools for storing and evaluating data generated by the protocols we examined in this project. We recognize the need to consider the broader use of data generated by different phases of the Regional Sediment Assessment and to design the information management tools to serve those uses. We have identified the following initial steps to improve upon the work that has already been completed:

- Develop a guide to using the CSUMB MS Excel tool for data entry and analysis of dry-sieved bulk samples,
- Design reports that can be generated by the MS Access database of pebble count data, photographs, and field notes.
- Develop a guide to using the MS Access database.

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